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The Swedish Shale Oil Industry

Excluding eastern Europe, the European continent lacks oil, and up to about two thirds of its oil requirements is dependent on overseas or other foreign oil producing centers. And since oil is the key commodity for the maintenance of the industrial standard of most countries, the search for and the development of suitable fuel substitutes have long been the primary aim and ambition of European scientists. Shale is one of the products which, to a certain extent, may solve the struggle for a domestic oil production in countries without their own petroleum resources. Some shale deposits contain organic substances which may be transformed to oil by different methods. The content of organic substances found in European shales varies from 3 to 20 percent, the yield of oil from such shales varying accordingly.

The European shale oil industry was developed already in the middle of the 19th Century, England and Estonia being the pioneers. The industry, however, has hardly been in a position to compete with the petroleum industry with its abundant flow of oil from rich and well-located wells. At any rate the shale oil industry has been maintained for national reasons and for the same purposes as, for example, many of the American stripper wells.

The Swedish shale oil industry is of recent origin. In the early twenties a small plant was constructed at Kinne Kleva south of Lake Vänern, where bituminous shale rock occurs. Later surveys carried out by the Swedish Geological Research Institution, proved that oil shale deposits were to be found at Kvarntorp in the province of Närke, the very place where the plants of Svenska Skifferolje Aktiebolaget (Swedish Shale Oil Co. Inc.) are now located.

Immense quantities of oil shale are submerged here below a shallow layer of erosion soil and limestone. The stratum of shale is about 50 feet deep and tilts slightly (some 8 ‰) towards the

south. The organic substances embedded in the shale varies from 5 to 6 percent and yield about an equivalent percentage of oil. The shale deposits in this area would allow an extensive oil production for centuries to come.

The Purpose of the Svenska Skifferolje Aktiebolaget

The Swedish prewar oil consumption was rather high compared to the average European consumtion *per capita*, and in 1939 reashed some 1,300,000 cubic meters (approximately 8,5 mill. barrels). Incidentally, Sweden's present oil comsumption is far above the prewar level, the shortage of coal intensifying the demand for all kinds of fuel oils On the other hand the gasoline consumption has not yet reashed the normal level.

Shortley after the outbreak of World War II the Swedish oil imports decreased substantially and ceased completely in April 1940, when the Germans invaded Norway. Afther that and during the war, only limited quantities of oil were imported. The severe oil shortage in Sweden called for drastic measures in order to avoid a complete collapse of our transport system. The utilization of domestic sources of supply was urgent, and the Swedish Government therefore founded the Svenska Skifferolje Aktiebolaget in January 1941. The company was formed as an incorporated body, the federal government holding all shares.

The construction andeerection of the plants proceeded in a rather stepped-up tempo, and already in 1943 more than 40,000 cubic meters (300,000 barrels) of oil were delivered from Kvarntorp. However, being far from sufficient this output led to an immediate doubling of the production program. During the last few years the annual production of our company, is estimated at about 85,000 cubic meters of oil (550,000 barrels), i. e. some 6.5 percent of Sweden's total prewar consumption.

The oil produced at Kvarntorp is processed and refined to gasoline and to kerosene (tractor distillate) and to various types of fuel oils (domestic and industrial fuels). The oil products derived from crude shale oil comprise about 35 percent gasoline, 5 percent kerosene and 60 percent heavy oils (fuel oils). The derivatives are

of high quality and well comparable with any type of similar commercial product in the world market.

Being a straight run product the gasoline produced has a rather high octane value (70/72 U. S. motor method), chiefly due to rich aromatic hydrocarbons in the oil. The gasoline also complies with the ASTM:s tentative specifications; designation D 439-37 T.

Distillate fuels produced at Kvarntorp are of average good quality as compared with similar products imported into Sweden. A very low pour point is characteristic for the oils in question, the second grade fuel (domestic heating) and the third grade fuel (industrial heating) having pour points of 60° and 30° C below zero respectively.

By-products

Incidentally, a shale oil industry based only on the production of different types of oil has a long way to go to solve the technical- and economic problems of bringing down production costs to normal and competitive levels. The roadmarks point to an aggregate production of oil in connection with a widespread manufacture of by-products, or possibly vice versa. This objective has consequently been instrumental for the introduction of rather extensive research activities carried out by the company ever since its foundation. The combined production of a string of different products derived from shale is the ultimate objective of the scientific and industrial efforts pursued at Kvarntorp, and ind accomplishing this it may be said the company has entered a rather new and unique line of industrial activity.

Simultaneously with the oil production at Kvarntorp, the plants also manufacture sulphur, quicklime (fertilizer), ammonia sulphate, gas, tar, and different types of slag. In order to utilize the abundant supply of hydrocarbon gases obtained at the plants, a liquified gas plant is being built, American entrepreneurs being attached to the construction and delivery of the different units. The annual capacity of the liquified gas plant is estimated at some 160,000 barrels, some products of which will be processed into highly refined and valuable chemicals.

The total production of the above mentioned by-products, measured in tons, is at present not far below the total production of oil. When our construction programs — which also include the manufacture of building materials — are carried out within three or four years, the production of different by-products will far exceed the production of shale oil, which it is anticipated, will total 115,000 m^3 (750,000 barrels) in 1950.

The annual production of sulphur at Kvarntorp amounts to 22,000 metric tons. The product is highly refined — 100 % pure — and one of the highest grades available on the sulphur market. The sulphur is delivered essentially to the Swedish pulp industry. This year two lime units of partly new construction have been erected, and together with a third and a fourth unit planned, the production of quicklime will reach about 60,000 metric tons in 1947. The production of ammonia sulphate is about 1,000 metric tons a year.

Some of the gas produced at Kvarntorp is piped to Örebro, which city receives its total requirements from our company, However, the city of Örebro consumes only about 5 percent of our gas production, the remainder at present being transformed to steam or electrical power through turbines.

Distribution

All products produced at Kvarntorp are distributed on the Swedish market in competition with other distributors or producers. Whereas in many other countries the shale oil industry is directly subsidized by tax-exemption or by import duties, no such arrangement is applicable to the Swedish shale industry.

This short study of the general problems underlying the progress of Svenska Skifferolje Aktiebolaget has been of a summary nature. Such a survey cannot embrace all the complicated technical and financial questions, which an industry of a partly new an unique character involves. Many problems are not even solved yet.

In turning away from the general problems connected with the industry, the specific manufacturing methods employed at Kvarntorp, will be described in the following chapter.

Production methods

About 4,000 tons of shale are mined every 24 hours. The shale rock is loaded with huge shovels on specially constructed 8 to 10-ton trucks and transported to breakers. After having passed through a single roll crusher, the heavy broken shale is carried on conveying belts to a separating house, where the concretion limestone is picked by hand. The shale, which then passes through the fine-crusher, holds only about 2 percent concretion limestone. The shale is then crushed in two breakers to sizes suitable for the different stills, and finally passes a granulator, which separates it into different granules.

The shale oil plants at Kvarntorp comprise one Bergh plant accomodating 3 stills, 2 channel stills, (which have successfully been employed in Estonia) as well as one retort still in some ways resemblying the types that are used in Scotland, in addition to an electrothermic plant, invented by Dr. Fr. Ljungström, where oil is distilled direct from the shale *in situ*.

The Bergh system

The Bergh system was invented in about 1920 by the mining engineer S. V. Bergh. This system was tested in a half-size experimental plant at Stockholm in 1922, subsequently in a full size experimental plant, and later on in a commercial-size plant at Kinne Kleva. It has been further improved at Kvarntorp.

The shale, crushed to 5—27 mm particles, is charged into vertical retorts of about 8 feet length an 8 inches diameter. The shale is passed slowly through the retorts in such a manner that the distilled and burned shale ash is continuously discharged by means of special dischargers and carried away on conveyers. The distillation heat is produced by burning the distilled shale coke at a temperature of 800—900° C in a combustion chamber, immediately below the retort. The combustion gases pass the outside of each series of five retorts embedded in a walled combustion chamber. To prevent the combustion gases from being absorbed by the oil gases, a certain pressure equilibrium must exist between the oil

gases and the chimney draft. In the hot zone of the combustion gases, steam is produced in La Mont coils, as well as in a boiler outside of the retort. A total of 15 tons 350□/sq. inch. of steam are produced per hour at a capacity of about 20 tons shale. By using the heat-value of the distilled shale coke partly for the distillation of the new shale and partly for the steam production, this method is very heat saving. Although it is extremely difficult to separate the combustion zone from the oil gas zone about 90 percent oil-yield is accounted for.

The oil gases proceed to a condensation plant, where a light oil and a heavy oil fraction is drawn off by means of a heat exchanger. The light oil fraction is processed further to gasoline and kerosene; the heavy fuel oil fraction being suitable as fuel oil in its present state. The uncondensable gas in the condensation chamber, containing hydrogen sulphide, and with a heat value of about 5,000 Kcal/Nm^3, is piped to the sulphur plant via a gas tank. A Bergh still house with a capacity of about 500 tons of shale per 24 hours consists of 1,120 retorts, arranged in 16 blocks with 70 in each block. Each block consists of 14 boxes with 5 retorts in each box.

AB Industrimetoder system

These stills consists of one 200 feet long horizontal, circular tunnel with a diameter of 12 feet. The shale is passed through this still in special perforated trucks. Each truck holds about 3 tons shale. The still is equipped with heat tubes, through which the combustion gases pass. These gases are generated in three special gas heated furnaces beside the still. The steam temperature of the gases from the three furnaces are 750, 680 and 580° C, while the temperature in the three terminal sections is 320, 400 and 440° C respectively. The combustion products thus do not come into contact with the oil gases as in the Bergh method. In order to increase the heat transfer from the heat tubes to the shale, the oil gases inside the still are made to circulate by means of fans, placed on the still's top. The oil gases are drawn off at the last section and delivered to a condensation plant.

The gaseous heavy oil fractions, suitable as fuel oil, are separated by washing the gas with circulating and condenced heavy-oil in two scrubbers, connected in series. The gaseous light oil fractions is condonsed by water-cooling the gas in three tube coolers. The uncondensable gas is piped to the sulphur works. The rest of the coke left in the trucks, is discharged from the tunnels and further burned for the generation of steam.

The Rockesholm metod

The third process is based on the Scotch method, modified by chief engineer Hultman and mining engineer Gustafson. The still is called the Rockesholm furnace named after Rockesholm in Närke, where the first experimental plant was built in 1916—1918. The crushed shale is charged into a vertical cast-iron retort of 26 feet length and 2 feet diameter, through which it passes slowly. The bottom of the retort, being somewhat wider than the top, is made of schamotte brick. The heating of the retort is arranged indirectly in such a manner that the combustion gases from the gas burners, placed in a crown at the bottom of the retort, pass along the outside of the retorts i walled combustion chambers, the temperature being maintained at a maximum of 840° C. By injecting steam at the retort's bottom, considerable quantities of gas is obtained. Caustic ammonia formed during the process and soluble in the condensation water is transformed to ammonia sulphate.

The oil gases drawn off at the upper part of the retort, are condensed in tube coolers to a medium oil fraction. This fraction is in turn distilled to gasoline and fuel oil. The discharged shale coke is burned for the generation of steam in a similar manner as in the »industry» stills. A still house with a capacity of 500 tons of shale per 24 hours contains 72 retorts.

The electrothermic method

Several scientists have tackled the problem of producing oil from shale *in situ*, i. e. in its natural or original position. This method, invented at Kvarntorp by Dr. Fr. Ljungström and based

on heating the ground electrically, worked out quite satisfactorily. The ground above the shale is marked up into hexagonal sections in whose corners pipes containing electrical heating appliances are driven down to the bottom of the shale structure. Pipes are also placed in the centers of the hexagonal sections through which the oil gases formed through the heating of the shale are conducted to the condensation plant.

The electrothermic method is based upon the availability of sufficient quantites of comparatively cheap electric power.

Conclusions

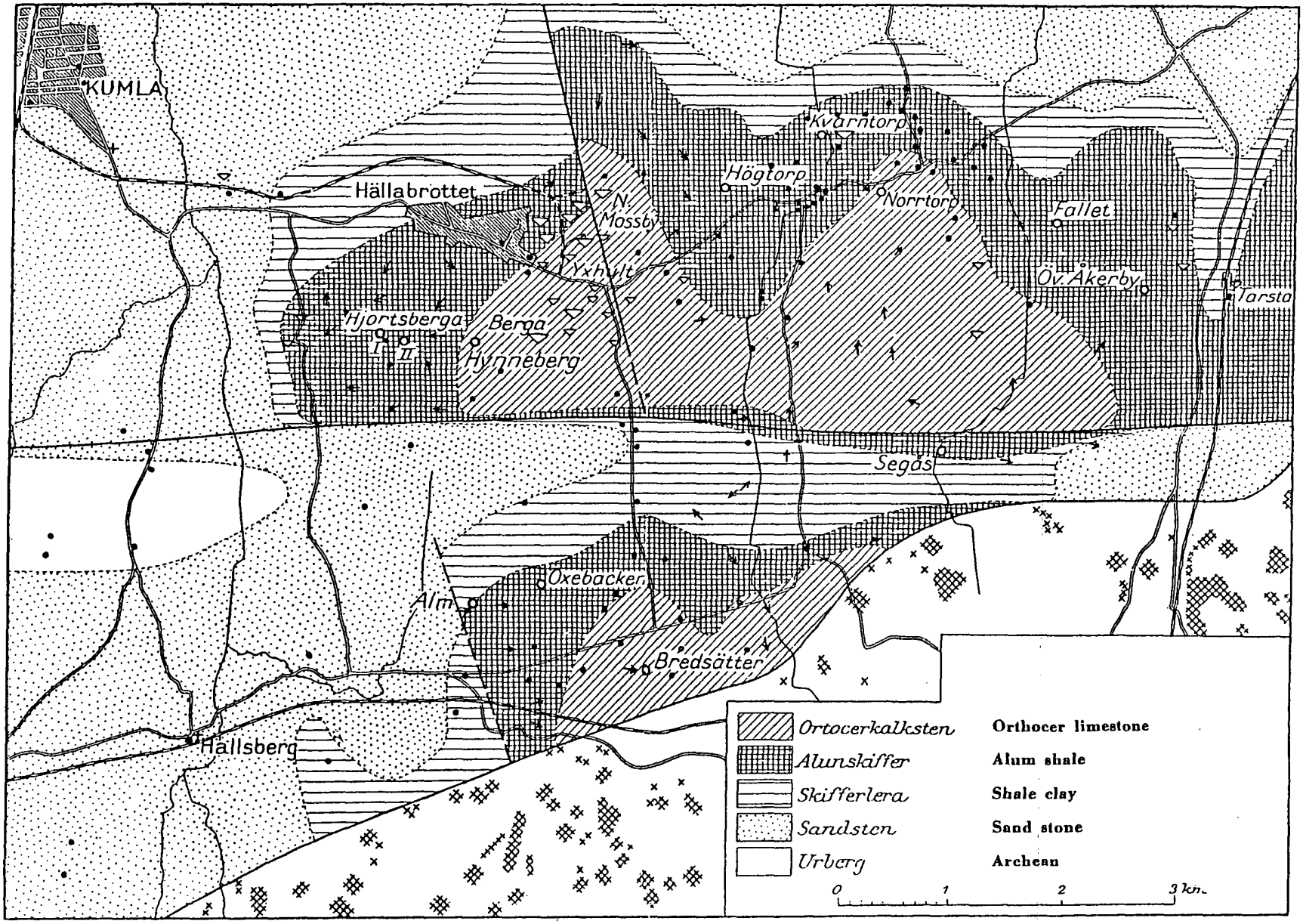
All pyrolysis-gases drawn off from the condensation system is piped to a gas tank, through which pressure balance and gas homogeneity is obtained when it is distributed to three sulphur plants, where elementary sulphur is secured by separating about 20 percent of the hydrogen sulphide which the gas contains. The sulphur produced is liquified and poured into concrete basins at a temperature of 140° C.

The gas, free from hydrogen sulphide, still holds some light hydrocarbons forming light gasoline, with about 70 percent hydrocarbons below 100° C. This light gasoline is absorbed in 4 scrubbers, 90 feet high, where it is washed out at a low temperature with suitable absorption oils. The absorption oil, saturated with 3—4 percent light gasoline, proceeds to a distiller, where the gasoline is distilled with water vapor.

Due to the rather special nature of the shale gasoline, the refining processes are specially developed to obtain a high-quality product with a minimum of losses. The final product is absolutely stable having a low sulphur content and of high quality.

The gas production at Kvarntorp is of special interest, the gas being produced at a rate of about 250,000 m^3 per 24 hours. The liquified petroleum gas derived herefrom contains a mixture of gaseous hydrocarbons with 3—4 carbon atoms. These hydrocarbons are suitable for the production of high-octane motor fuels, for the manufacture of chemical products, and is at the same time a first class industrial and domestic fuel.

Sketch of the shale deposits in S. E. Närke



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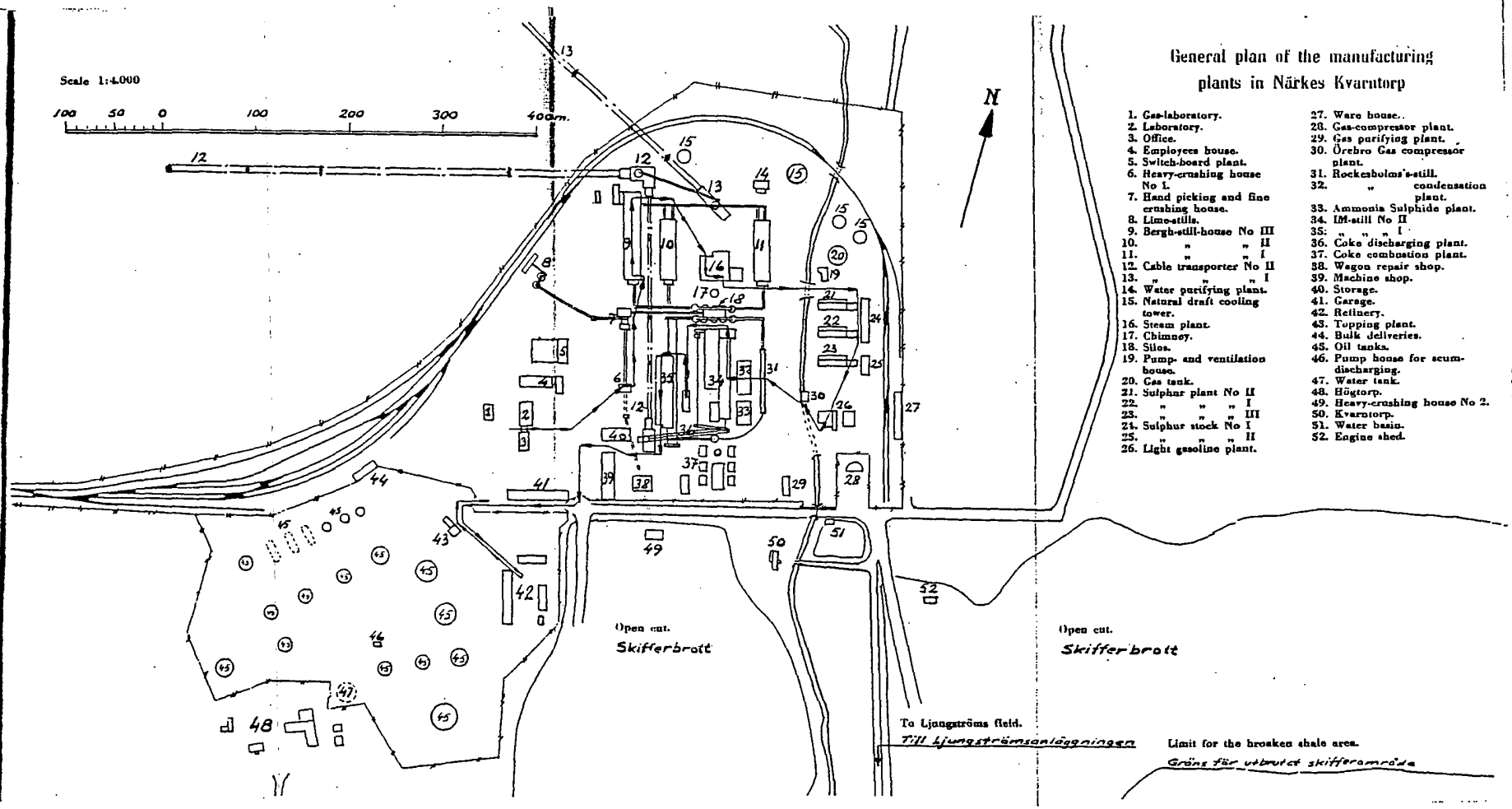

General plan of the manufacturing plants in Närkes Kvarntorp

1. Gas-laboratory.
2. Laboratory.
3. Office.
4. Employees house.
5. Switch-board plant.
6. Heavy-crushing house No I.
7. Hand picking and fine crushing house.
8. Lime-stills.
9. Bergh-still-house No III
10. „ „ II
11. „ „ I
12. Cable transporter No II
13. „ „ „ I
14. Water purifying plant.
15. Natural draft cooling tower.
16. Steam plant.
17. Chimney.
18. Silos.
19. Pump- and ventilation house.
20. Gas tank.
21. Sulphur plant No II
22. „ „ „ I
23. „ „ „ III
24. Sulphur stock No I
25. „ „ „ II
26. Light gasoline plant.
27. Ware house.
28. Gas-compressor plant.
29. Gas purifying plant.
30. Örebro Gas compressor plant.
31. Rockesholms's-still.
32. „ condensation plant.
33. Ammonia Sulphide plant.
34. IM-still No II
35. „ „ „ I
36. Coke discharging plant.
37. Coke combustion plant.
38. Wagon repair shop.
39. Machine shop.
40. Storage.
41. Garage.
42. Refinery.
43. Topping plant.
44. Bulk deliveries.
45. Oil tanks.
46. Pump house for scum-discharging.
47. Water tank.
48. Högtorp.
49. Heavy-crushing house No 2.
50. Kvarntorp.
51. Water basin.
52. Engine shed.